II. *Mariner* Venus–Mercury 1973 Project

A. Project Description and Status

1. Description

The *Mariner* Venus–Mercury 1973 Project was authorized in December 1969 to conduct the first dual-planet mission. The primary objective is to conduct exploratory investigations of the planet Mercury's environment, atmosphere, surface, and body characteristics, and to obtain environmental and atmospheric data on the planet Venus (first priority assigned to Mercury investigations). The secondary objectives are to perform interplanetary experiments enroute to Mercury, and to obtain experience with the gravity-assist mission mode.

A single *Mariner* spacecraft is planned for launch by an *Atlas/Centaur* vehicle from Cape Kennedy in October 1973. The Venus encounter, in February 1974, will provide both an opportunity to obtain scientific data at that planet and the necessary energy, by means of gravity-assist, to reach Mercury some 7 wks later. The spacecraft design is expected to resemble that used in the *Mariner* Mars 1969 mission and that being developed for the *Mariner* Mars 1971 mission, with appropriate modifications defined by the Venus–Mercury mission requirements. The scientific experiments, assumed to include television and other planet-oriented elements together with interplanetary fields-and-particles investigations, will be selected by NASA Headquarters during July 1970. The Deep Space Network and other NASA facilities will be committed to support the mission. It is planned that a System-Integration Contractor will be selected in early 1971. The Contractor's effort would encompass the spacecraft detail engineering, system assembly, test and operations, and selected support to other elements of the Project.

2. Status

A briefing of some 45 industrial firms was held on February 24, 1970 to acquaint them with the preliminary Project planning and to solicit their suggestions regarding

the most cost-effective approach to use in implementing the Project. The industry suggestions and an internal system contracting study will form the basis for establishing the detail implementation plans for the Project.

B. Guidance and Control

1. Power Subsystem

a. Introduction. The *Mariner* Venus–Mercury 1973 (MVM '73) spacecraft power subsystem is presently planned to be a modification of the *Mariner* Mars 1971 (MM '71) design. Modifications are required primarily for operation in the vicinity of Mercury, as well as for a revised power profile. The following text describes why these changes are required and presents a preliminary description of the overall power subsystem.

b. Power requirements. A preliminary power profile depicting the subsystem power requirements for four key operational modes near Earth and Mercury is shown in Table 1. Examination of these requirements, which take into account the power conditioning and conversion efficiencies, shows a maximum raw power requirement of 538 W in one of the near-Mercury modes. A preliminary functional block diagram of the MVM '73 power subsystem components is shown in Fig. 1. A tentative science payload is included; however, final selection of the science payload will not be made before July 1970.

c. Solar panel. Because of a significant increase in temperature, associated with an increase in solar intensity at Mercury, two types of solar panel configurations are currently being investigated. The present baseline philosophy is to make use of two MM '71-type panels by incorporating a spacecraft capability to include a one-step solar panel tilt to a predetermined angle of incidence. This reduces the solar panel temperature to an acceptable value. At present, 140 and 128°C temperatures are expected at Venus and Mercury, respectively. The objective of the tilt is to provide solar panel output voltages that are compatible with the MM '71 power subsystem components (37.5–50 Vdc). As a variation to this approach, the concept of a panel with continuously varying angle of incidence is also being investigated. Preliminary analysis of the two-panel one-step tilt configuration shows that available power at near-Earth is approximately 409 W at 50 Vdc, which increases to approximately 475 W at 37.5 Vdc at Venus. Following Venus encounter, the panels are tilted to an angle of 60 deg and the power remains at 475 W, whereas the voltage increases to 50 Vdc. Available power at Mercury increases to 540 W at 37.5 Vdc. As of this reporting period, with power requirements in the preliminary stages, it appears that additional solar panel area is required over that provided by the MM '71 design. A tabulation of total raw power required and available power and output voltage is given in Table 2 for several key operating modes and for the two types of solar panel configuration being investigated.

The second solar panel approach being investigated is to consider four non-tiltable panels. This configuration will require a newly developed technique for limiting the solar radiation actually reaching the cell. Techniques being considered include selective filtering or reflective coatings. Even with these controls, the panel output voltage will drop to approximately 44 Vdc, depending on the actual operating temperature of the panels. Adequate power and voltage within power conditioning operating tolerances (37.5–50 Vdc) is provided in all operational modes. By July 1970, it is expected that the results of the current solar panel advanced development effort will define anticipated performance in sufficient depth, to allow selection and sizing of either the two solar panel tilting system or the four panel non-tilting configuration.

d. Battery. The MM '71 26-cell 20 A-h nickel–cadmium battery is currently planned for use on this mission. Energy demands to be supplied by the battery may range up to approximately 450 W-h. This demand may occur during any of three planned maneuvers, each of which may last up to 80 min. With the addition of the launch mode, sun occultation at Mercury and a possible fourth maneuver, a total of six battery discharge/charge cycles are required.

The MM '71 battery charger may be used for battery charging which occurs immediately after acquiring solar panel power. The charger provides a maximum charging current of 2 A (c/10 rate) and a low-rate charge rate of 0.65 A (c/30 rate). The charger has the capability of accepting an input voltage varying from 25 to 50 Vdc.

e. Power conditioning and distribution. A preliminary functional block diagram of the MVM '73 spacecraft power subsystem is shown in Fig. 1. Solar panels provide raw power through blocking diodes to the dc bus.

The main booster regulator converts solar panel voltage to a regulated 56 Vdc at a tolerance of $\pm 1\%$. An identical standby booster regulator serves as a backup to

Table 1. Preliminary power profile

Item	Key operational modes			
	Earth		Mercury	
	High-rate battery charge (no science)	Low-rate battery charge (Earth science on)	High power transmission, low-rate battery charge (all science on, gyros on)	High power transmission, low-rate battery charge (all science on, gyros off)
Science instruments				
UV spectrometer	0.0	0.0	3.0	3.0
Plasma science	0.0	13.0	13.0	13.0
Film imaging	0.0	60.0	60.0	60.0
Gamma ray spectrometer	0.0	3.0	3.0	3.0
IR radiometer	0.0	0.0	2.5	2.5
DC magnetometer	0.0	4.0	4.0	4.0
Plasma wave	0.0	3.4	3.4	3.4
Charged particle	0.0	4.5	4.5	4.5
Science data subsystem	0.0	25.0	25.0	25.0
Total science output, W	0.0	112.9	118.4	118.4
Engineering subsystems				
Thermal control 1	40.0	0.0	0.0	0.0
Scan electronics	4.3	26.0	26.0	26.0
Data storage	10.0	18.0	18.0	18.0
Flight telemetry	15.2	15.2	15.2	15.2
Flight command	3.0	3.0	3.0	3.0
Radio frequency	24.0	24.0	24.0	24.0
Pyro	1.0	1.0	1.0	1.0
Central computer and sequencer	18.5	21.5	21.5	21.5
Attitude control	27.0	11.0	27.0	11.0
Gyro 1	12.0	0.0	12.0	0.0
Power distribution	10.0	10.0	10.0	10.0
Total engineering output, W	165.0	129.7	157.7	129.7
Total 2.4-kHz main inverter output, W (efficiency)	165.0 (0.904)	242.6 (0.915)	276.1 (0.915)	248.1 (0.915)
Total 2.4-kHz main inverter input, W	182.5	265.14	301.6	271.0
Scan motor, 400 Hz, 1-phase (efficiency)	0.0 (0.797)	11.79 (0.797)	11.79 (0.797)	11.79 (0.797)
Gyro 2, 400 Hz, 3-phase (efficiency)	11.6 (0.775)	0.0 (0.775)	11.6 (0.775)	0.0 (0.775)
Total boost regulator output required, W (efficiency)	194.1 (0.874)	276.93 (0.886)	324.99 (0.886)	282.79 (0.886)
Total boost regulator input, W	222.08	312.56	366.80	319.17
Unregulated dc power required				
Boost regulator	222.08	312.56	366.80	319.17
Battery charger	95.00	35.00	35.00	35.00
Traveling-wave tube	57.00	57.00	93.00	93.00
Boost regulator failure sensor	1.50	1.50	1.50	1.50
Thermal control 2	25.00	25.00	25.00	25.00
Total power, W (diode efficiency)	400.58 (0.97)	431.06 (0.97)	521.3 (0.97)	473.67 (0.97)
Total raw power required, W	413	444	538	489

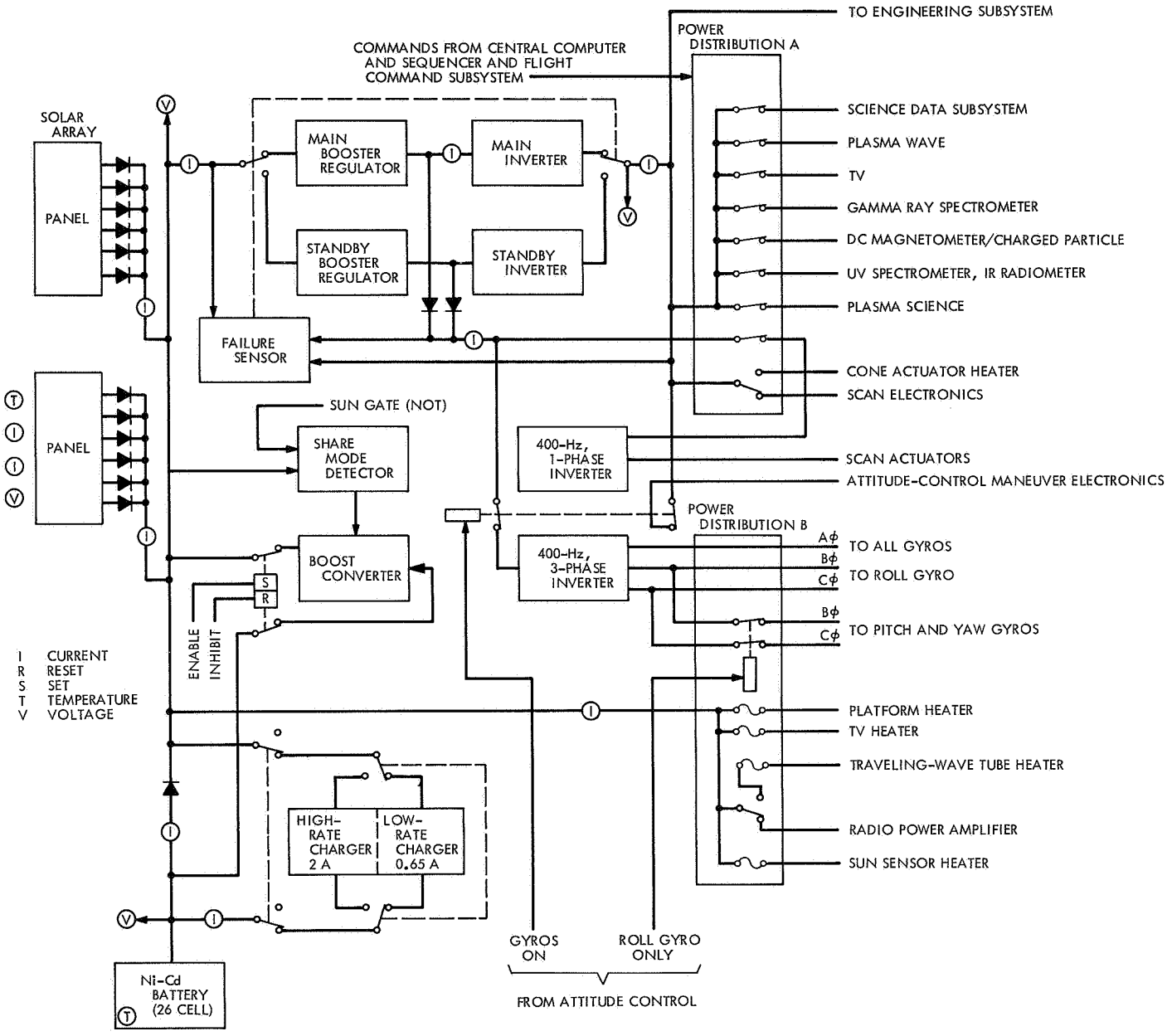

Fig. 1. Power subsystem functional block diagram

Table 2. Comparison of preliminary power required vs power available with operating voltages for both the tilting and non-tilting solar panels

Parameter	Key operating modes						
	Cruise (near Earth)			Venus	Mercury		
	Low-rate battery charge (no science)	High-rate battery charge (no science)	Low-rate battery charge (science on)	High-power transmission, low-rate battery charge (science on)	High-rate transmission (gyros on, science on)		High-rate transmission, low-rate battery charge (gyros off, science on)
					No battery charge	Low-rate battery charge	
Power required, W	303	413	444	485	504	538	489
Available power (tilting panel), W	409 (50 Vdc)	409 (50 Vdc)	409 (50 Vdc)	[a]475 (37.5 Vdc) [b]475 (50 Vdc)	540 (37.5 Vdc)	540 (37.5 Vdc)	540 (37.5 Vdc)
Available power (non-tilting panel), W	496 (50 Vdc)	496 (50 Vdc)	496 (50 Vdc)	1100 (44 Vdc)	655 (37.5 Vdc)		655 (37.5 Vdc)

[a]Contingency not included: before tilt.

[b]Contingency not included: after 60-deg tilt.

the main booster regulator and will provide power in case of failure of the main booster regulator. Switchover is controlled by onboard detection of over-or-under voltage at the output of the main booster regulator. The maximum power output of both the MM '71 main and standby booster regulators is 295 W. However, the preliminary power requirements determined during this reporting period require a redesign for increased power output, as shown in Table 3.

The main inverter output is designed to provide 2.4 kHz ±0.01% single-phase, square-wave power at 50 V (rms) +2 or −3% from a regulated 56 Vdc ±1% input. Timing signals to the central computer and sequencer are provided from the main inverter. In event of failure of the main inverter, the system will switch to a standby inverter with identical output characteristics. The maximum power output of the MM '71 main and standby inverters is 250 W. At the present time, a redesign is being contemplated based on the preliminary requirements shown in Table 4.

The 400-Hz inverter consists of both single-phase and three-phase outputs. The output characteristics of the single-phase portion, including both amplitude and frequency, are 28 V (rms) ±5% square wave and 400 Hz ±0.01% in the normal mode, respectively. Average power output is 15 W at 28 V with a peak loading of 21 W. The 400-Hz three-phase power output characteristics, including both frequency and amplitude, are 400 Hz ±0.01% in the normal mode and 27.2 V (rms) ±5% line-to-line, quasi-square wave, respectively. Average power of the three-phase output is 12 W with a peak of 15 W.

Table 3. Booster regulator 56 Vdc power available vs power required

Item	Earth		Mercury	
	Min	Max	Min	Max[a]
2.4-kHz main inverter	182.5	242.6	271.0	301.6[a]
Scan motor	0.0	11.8	11.8	11.8
Gyro 2	11.6	0.0	0.0	11.6[a]
Total power required, W	194.1	254.4	282.8	325.0[a]
Total power available (MM '71), W	295	295	295	295

[a]All-axis inertial control at encounter: includes all science on; gyro 1 on (12 W); attitude control increase (16 W).

f. Power subsystem weight. A weight breakdown of the current MVM '73 power subsystem and design status is shown in Table 5.

Table 4. Main inverter 2.4-kHz power available vs power required

Item	Earth		Mercury
	Min	Max	
Engineering subsystems	165	129.7	129.7 (157.7)[a]
Science instruments	0	112.9	118.4[b]
Total power required, W	165	242.6	248.1 (276.1)[a]
Total power available (MM '71), W	250	250	250

[a]All-axis inertial control at encounter: includes all science on; gyro 1 on (12 W); attitude control increase (16 W).

[b]Includes 3-W increase for UV spectrometer, and 2.5-W increase for IR radiometer at Mercury only.

Table 5. Power subsystem weight breakdown

Item	Weight, lb	Design status
Solar cells (not including structure, mirrors) EST.	20.0 (est)	New
Battery, including chassis, Ni–Cd	65.0	*Mariner* Mars 1971 (same)
Battery charger	3.5	*Mariner* Mars 1971 (same)
Main inverter, 2.4-kHz (2)	5.90	*Mariner* Mars 1971 (modified)
Boost regulator (2)	11.6	*Mariner* Mars 1971 (modified)
Inverter (400-Hz, 1- and 3-phase)	3.7	*Mariner* Mars 1971 (same)
Power control	2.44	*Mariner* Mars 1971 (modified)
Power source logic	10.75	*Mariner* Mars 1971 (modified)
Power distribution	5.0	*Mariner* Mars 1971 (modified)
Total	127.89	